# Design and Analysis Performance of IoT-Based Water Quality Monitoring System using LoRa Technology

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***Abstract*** **– Water quality is one of the most important variables impacting human life. Generally, water quality measurements must be conducted on-site. If the region to be investigated is large, several test locations will be required. Repeated evaluations of water quality will be complicated and time-consuming. Therefore, a real-time water quality monitoring system is required to protect and monitor the water in order to take proactive measures for contamination. This project focuses on the aforementioned concerns and uses LoRa technology and the Node-RED application to develop environmental sensors that monitor and display water quality. It is the measurement and collection of data on water quality parameters, including temperature, electric conductivity, pH, air quality, and turbidity, according to the region requiring analysis. The microcontroller processes the sensor data before transmitting it via the wireless network to the database, where it is displayed on the Node-RED dashboard. The experimental results demonstrated that a range of 2.0 km can be used to transmit information in areas where LoRa technology encounters obstacles. Furthermore, the IoT-based monitoring system is able to monitor water quality in real time and display a Node-RED dashboard. It was determined that usability assessments were more efficient and convenient.**

***Keywords*** **– water quality, internet of things, LoRa technology.**

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## 1. Introduction

Water is a natural resource that is important to human life for consumption. On the Earth, there are approximately 326 million trillion gallons of water. Freshwater makes up less than 3% of the total amount of water, and more than two-thirds of it is locked in glaciers and ice caps. Although it is a natural resource that is abundant, it can be used only 0.04% [1], [2]. Freshwater sources can be divided into 2 types: ground water sources and surface water sources such as rivers, canals, waterfalls, dams, reservoirs, etc. At the same time, industrial and agricultural activities expand rapidly and have a significant effect on environmental pollutants due to generating waste and chemical leaks. It is crucial to ensure that water resources remain healthy and consumable. With increasing globalization, the world is facing the problems of water demand and contamination. Water quality attention is important to avoid any quality problems caused by water consumption from various activities. Water quality parameters can be separated into three categories. The first category is physical characteristics, including conductivity, turbidity, chromaticity, temperature, smell, and color. The second category includes a variety of chemical properties, such as pH, dissolved oxygen, chemical oxygen demand (COD), biochemical oxygen demand (BOD), total organic carbon, heavy metal ions, and nonmetallic poisons. The third category is microbiological, which includes all bacteria and coliforms [3]. The traditional way to check the quality of water is to collect water samples from different sites by hand, which is a boring and time-consuming task. As a result, researchers are interested in water quality evaluation using Internet of Things (IoT) technologies, which is an interesting approach nowadays. IoT refers to devices that are connected to a network and, more recently, to the value chain that is created when things, data, human, and services are all connected. The sensors and other IoT devices must be connected to the network as they are all accumulator-powered.

In addition to communication, the IoT now plays a significant role in data monitoring, recording, storing, and displaying. IoT solutions provide new avenues for pursuing cost-effective resources [4]. IoT technology has been used more often recently to address environmental issues like these: air quality, water pollution, and radiation pollution [5], [6], [7].

According to recent research, they have utilized IoT technology to provide real-time monitoring to optimize processing and be more efficient in water quality management. Furthermore, LoRa and Low Power Wide Area Network (LPWAN) technologies are popular network protocols in IoT systems due to their versatile and robust technical characteristics, as well as their ability to achieve long communication ranges with low power, low cost, and high data rates when implemented in systems [8], [9], [10], [11]. However, the application of LoRa technology requires zoning or country considerations. This is because there is a requirement for each country to use LoRa devices at the specified frequencies [12]. For Thailand, the frequency range is 920–925 MHz, which is considered an unlicensed frequency with a transmit power of not more than 20 dBm (less than or equal to 100 milliwatts). Finally, for the application of roller technology, users need to understand the working principle of LoRa technology. This is a good guide to choosing the right equipment.

Therefore, the main purpose of this study was to design and analyze the performance of a water quality monitoring system that used IoT sensors for measuring water quality parameters such as temperature, electric conductivity, pH, air quality, and turbidity with LoRa wireless communication and was installed on the robot (boat) for community application. In addition, Node-RED technology was used to display information on water quality.

## 2. Methodology

This section describes the research methodology used with LoRa technology for analysis, design, and implementation of the performance of an IoT-based water quality monitoring system, which includes 5 sections as follows:

### *2.1. System conceptual design*

The IoT architecture is a framework that consists of physical components, technical setup and arrangement of the network, operating procedures, and data formats. The IoT architecture may be implemented quite differently. As a result, it must be flexible enough for open protocols to handle a wide variety of network applications. The most common and generally acknowledged structure is a three-layer architecture. In the initial stages of this IoT study, it was implemented.

The three layers that are indicated are perception, network, and application [13]. The IoT architecture used in this study is represented in Figure 1.

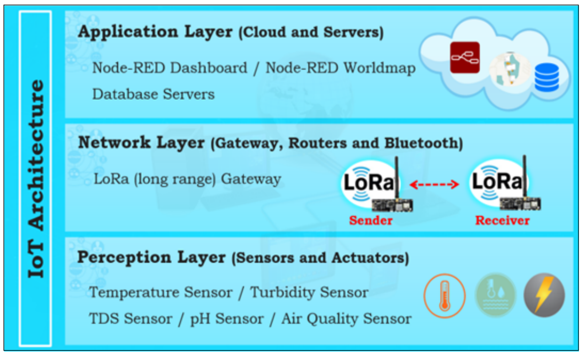



*Figure 1. Layered architecture of the proposed LoRa-based multi-sensor IoT system*

In the perception layer, sensors are connected to the network layer by a microcontroller board. In this study, the authors developed a sensor monitoring system utilizing a microcontroller board that transmits environmental data and collects values for temperature, conductivity, pH, turbidity, and air quality using LoRa technology. LoRa technology can be used to communicate with one another. The data is sent to the microcontroller board to be processed [14]. All the sensor readings are shown on the Node-RED application, which users can access from their computer.

### *2.2. LoRa technology*

LoRa (Long Range) is a generic term for a group of wide-area communication technologies with greater signal propagation range and better obstacle penetration. It operates in the radio frequency bands with no license required, at a frequency below 1 GHz (in Thailand, the frequency band is 920-925 MHz) and can be used in applications requiring transmission. In open-area testing, LoRa can support long-range transmissions of more than 10 km when used in challenging environments. The transmission distance is reduced to less than 1 km. The study analyzed the LoRa performance in terms of the doppler effect, which affects signal reception, and comparable speeds [15]. It reached the conclusion that the communication could be unworkable depending on the hardware configuration chosen. Additionally, it performed coverage of land and sea. LoRa technologies are used in two types: LoRa and LoRaWAN. In the case of LoRa, it will be used in a frequency band that does not require permission. Communication will focus on point-to-point between each LoRa active node. There is a limited-service range, but in the case of LoRaWAN, the LoRa node can communicate to the remote end node via the LoRa gateway, so the network will cover long distance communications similar to that of a WAN network [3], [16].

Besides, LoRaWAN communication is a media access control protocol (MAC) at the top layer of the physical layer. The three most common frequency bands that are used are 433 MHz, Europe (868 MHz), and North America (915 MHz) [17], [18], [19].

### *2.3. Design of sensing circuit*

The basic design behind all of this study is the use of sensors to measure parameters of water quality and the transmission of that information through LoRa wireless communication. It is comprised of two parts: a transmitter and a receiver. The transmitter consists of a TTGO LoRa32 development board and sensors that collect water quality parameters from water sources. The collected data is sent to the receiver through the LoRa communication function of the TTGO LoRa32, which receives the data on water quality and displays it on a Node-RED application. The diagram of water quality monitoring using IoT with LoRa wireless communication is shown in Figure 2. The system consists of several sensors and is used to measure the quality of water like temperature, conductivity, pH, turbidity, and air quality. The details of each device can be described as follows:

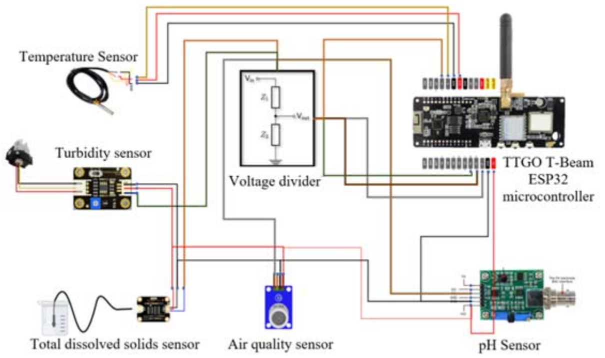



*Figure 2. Diagram of water quality monitoring system*

#### *A. TTGO T-Beam ESP32 microcontroller*

The TTGO T-Beam ESP32 is a microcontroller that connects all IoT sensors in a network to monitor environmental parameters. The EPS32 microcontroller uses LoRa modules for operating in the 868/915 MHz and supports GPS connectivity. This device will be responsible for sending, receiving, and processing the sensor data, then sending it to the application layer (see in Figure 1).

#### *B. Temperature Sensor*

The temperature sensor (DS18B20 Arduino) is used to monitor the coldness or hotness of the water, measured in degrees Celsius (°C) with a temperature precision of ±0.5 °C.

The operating temperature range is -55 to 125 °C (with an accuracy of -10 to 85 °C).

The temperature sensor was calibrated with a thermometer at various temperatures. In the test results, it was found that the temperature sensor had an accuracy of 94.05%. The temperature of water is important in deciding whether a particular source is suitable for human consumption and use. It also affects oxygen for many aquatic organisms. The WHO (World Health Organization) recommends that the water temperature must be between 20 and 30 °C [20].

#### *C. Total dissolved solids sensor*

The total dissolved solids (TDS) sensor is a device for measuring the electrical conductivity of liquids or total dissolved solids in water. Conductivity is measured as the ability of water to conduct electricity due to the presence of dissolved inorganic compounds and is recorded in units called "micro Seimens per centimeter" of water (μS/cm). The effect of water conductivity on aquatic animal survival and reproduction. In the case of high conductivity values, it may lead to conflict and other negative outcomes [21]. Therefore, it is important to evaluate electrical conductivity in order to maintain the quality of water. The TDS sensor used in this study has a measurement range of 0-1000 ppm and an accuracy of 10% of the full scale.

#### *D. pH Sensor*

The pH sensor (analog pH meter) is an instrument that measures the pH of any solution and is used to measure the acidity and alkalinity of water. It is widely used in a variety of applications, including aquaponics, aquaculture, and environmental water testing. In general, the pH sensor is designed to give a value from 0 to 14 according to the negative logarithm of the hydrogen-ion concentration. Mathematically, pH is referred to as pH = -log [H+]. In this case, the normal pH range of human life requires a pH level of about 6.0–8.5, which is the acceptable value for consumption [4], [22]. In this study, the pH sensor was calibrated with a pH meter (Mettler Toledo S210). The pH calibration powder is used to calibrate the accuracy of the electronic pH measurement probe. In the test results, it was found that the pH sensor had an accuracy of 96.95%.

#### *E. Turbidity sensor*

The turbidity sensor is used to measure the level of turbidity in the water. It measures the light's transmittance and scattering rate to find suspended particles in water. This rate changes depending on the quality of the total suspended solids (TSS). The most common turbidity values of water are defined in the range of 0.1–1000 Nephelometric Turbidity Units (NTU).

For water in rivers, the turbidity is up to 150 NTU [23], [24].

In this study, the sensor measures the light refracted in water and converts it to a turbidity value of 0–4.5 volts for analog output with 500 ms measurement accuracy. Turbidity was compared using volts to 0–1000 NTU. The turbidity sensor was calibrated to standard values. It was found that the device had an accuracy of 91.03%.

*F. Air quality sensor*

The air quality sensor (MQ-135 gas sensor) is one of the MQ Series sensors that are used to monitor the air quality and detect or measure nitrogen oxides, ammonia, carbon dioxide, benzene, alcohol, smoke, and other gases in the air using the principle of resistance change when absorbing gases. The sensor consists of an $Al_2O_3$ (Aluminum oxide) ceramic tube, a $SnO_2$ (Tin oxide) sensing layer, and a heating coil. The analog TTL runs on 5 volts, which means it can be used with most microcontrollers [25].

### *2.4. Node-RED application*

This section describes the flow chart of Node-RED for sensor monitoring and world map. Node-RED is a programming application for integrating hardware devices, application programming interfaces (APIs), and online services. It helps developers connect devices to APIs through a configuration web browser and work more flexibly. Node-RED is a recommended IoT platform that can be set up on personal computers to keep the platform safe and private. This application is extremely popular due to its graphical interface [26]. Moreover, it is a powerful tool for building IoT applications using visual programming. In the present study, the purpose of the Node-RED dashboard library is to add gauges, charts, serial ports, functions, and switches and use them to display the data from sensor information as shown in Figure 3.

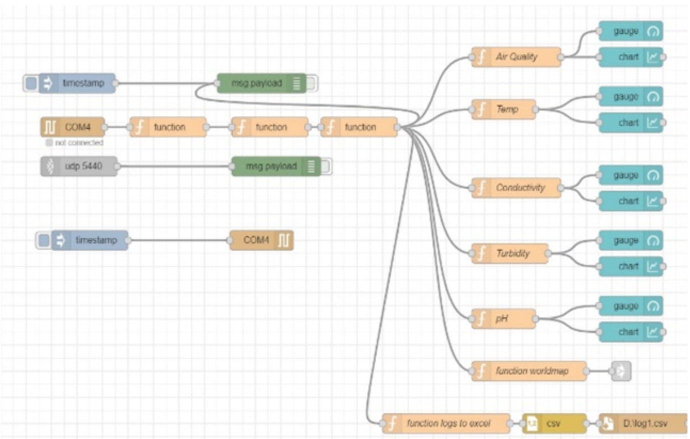



*Figure 3. Node-RED configuration for water quality monitoring*

Figure 4 depicts the Node-RED flow chart for the world map. We get the latitude and longitude of the map from the TTGO T-Beam GPS module of the ESP32 in order to evaluate it through the worldmap library.

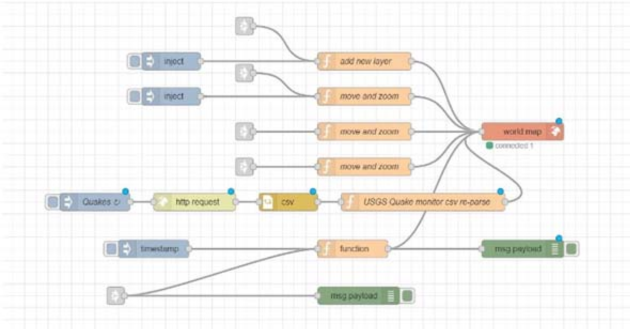
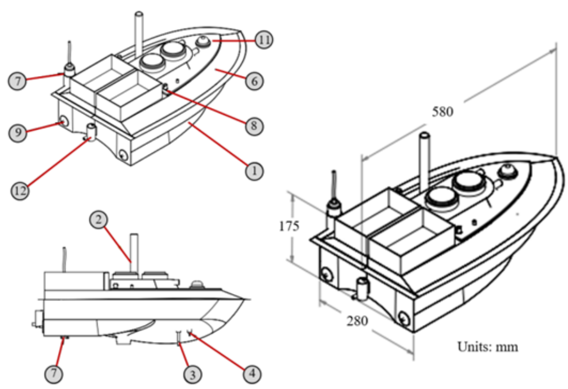



*Figure 4. Node-RED configuration for displaying map with worldmap library*

### *2.5. Prototype of smart boat collector for water quality monitoring*

A prototype of a mobile collector of water quality based on a wireless electric boat has been designed and developed to monitor water quality in water resources. The fuel cell used in this study has dimensions of 280 mm, 175 mm, and 880 mm for width, height, and length, respectively. An isometric view and the components of the mobile collector are shown in Figure 5. All of the sensors for measuring water quality with LoRa technology (TTGO T-Beam ESP32 microcontroller) were put in the mobile collector. The mobile collector is used to monitor water meters and measure the status of equipment by using LoRa to send meter reading instructions and data. The authors have developed an IoT-based Smart Water Quality Monitoring (SWQM) system that supports increased water quality measurement. on the five parameters of water quality, i.e., temperature, conductivity, pH, turbidity, and air quality. An overview of the mobile collector is shown in Figure 6.




**1** : Bottom Body **2** : TTGO32 **3** : Temperature Sensor **4** : TDS Sensor **5** : DC-DC
**6** : Top Body **7** : pH Sensor **8** : pH 4502C **9** : Motor RS775 **10** : Turbidity Sensor
**11** : Air Sensor **12** : Water pump

*Figure 5. Layout components of IoT-based boat collector*

*Figure 6. Overview of smart boat collector*

## 3. Results and discussions

In this study, the author utilizes the IoT technology to monitor water quality parameters such as temperature, electric conductivity, pH, air quality, and turbidity. The system uses TTGO T-Beam as a controller, a DS18B20 sensor for temperature, a TDS sensor for conductivity, a turbidity sensor for turbidity, a pH meter for pH, and an MQ-135 gas sensor for air quality. LoRa for data transmission communication and the Node-RED dashboard to be displayed on a computer. The data of water quality is displayed on the Node-RED dashboard every 1 second of those various parameters for real-time monitoring and can be automatically uploaded to the Node-RED dashboard in real-time monitoring information, which overcomes the short comings of traditional water quality monitoring systems. The water quality parameters being displayed on the Node-RED dashboard have been shown in Figure 7. In addition, Figure 8 represents the pinpoint location of the mobile collector by using the world map library in Node-RED.

*Figure 7. Water quality monitoring dashboard*

Figure 9 shows the range of situations in which the performance of LoRa-based data transmission can be tested. As shown in Figure 10, which represents the results of data transmission performance based on LoRa technology, it was found that the areas with LoRa technological obstacles could receive and send data sets at a distance of 2.0 km.

This could be used to send and receive data in areas with LoRa technology obstacles with an accuracy of more than 95.50% of our 600 data sets. In the case where the distance is longer, the signal of transmission through the LoRa technology will begin to weaken.

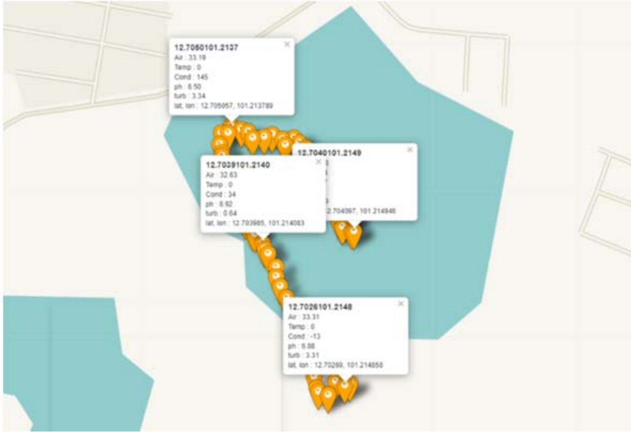


*Figure 8. Pinpoint location of world map*

*Figure 9. Data transmission performance based on LoRa technology*

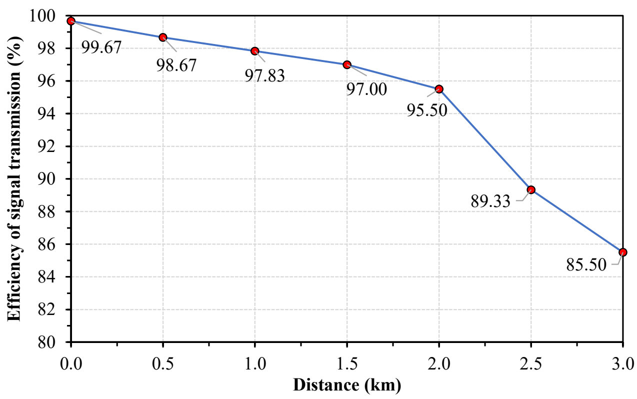



*Figure 10. Efficiency of signal transmission*

## 4. Conclusion

The objectives of the research were to design and analyze the performance of a water quality monitoring system based on IoT and LoRa technology with the Node-RED application for the design and component architecture and to evaluate how the water quality monitoring system was put into place.

In accordance with the region that requires analysis to have been done, it is a measurement and data collection of water quality parameters like temperature, electric conductivity, pH, air quality, and turbidity. The data from the sensors is processed using the TTGO LoRa32 microcontroller and transmitted via the wireless network to the database, where it is displayed on the Node-RED dashboard. The results of the experiment indicated that a distance operation of 2.0 km could be used to send and receive data in areas with LoRa technology obstacles with an efficiency of signal transmission of more than 95.50% of our 600 data sets over a distance of 2.0 km, which will reduce the amount of storage over longer distances. In addition, the monitoring system based on IoT is able to track water quality in real-time and display a Node-RED dashboard. The usability tests were found to be more convenient and time-efficient. This system can be integrated with innovative approaches like the smart city. As a result, the demand for a real-time monitoring system will develop. In the future, work will focus on adding the BOD/COD sensor to the system and making a new antenna for LoRa technology to improve signal transmission.

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